

Improvement of CERES Ed4 Clouds over Ed2 using C3M data

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Objective

CERES has two Clouds Editions

Edition 2 was delivered in 2004

Edition 4 was delivered in 2013

To find out the differences between the two versions and improvements of CERES Edition 4, by comparing both versions with CALIPSO.



Outline

- Data Product Used
- Cloud Detection Comparisons between CERES Ed4 and CALIPSO, and between CERES Ed2 and CALIPSO
- Cloud Top Height Comparisons Between CERES Ed4 and CALIPSO, and between CERES ED2 and CALIPSO
- Cloud Optical Depth Comparisons between CERES Ed2 and Ed4
- Summary



C3M product

C3M (CALIPSO, CloudSat, CERES, MODIS)

Collocated: Aqua - MODIS:

L1B --- MAC02 (radiance)

L1B --- MAC03 (geolocation)

L2 --- MAC04 (aerosol)

CALIPSO:

L2 --- Vertical Feature Mask (VFM)

L2 --- 5 km Cloud Profile (05kmCPro)

L2 --- 5 km Aerosol Layer (05kmALay)

L2 --- 5 km Cloud Layer (05kmCLay)

CloudSat:

L2 --- Cloud Scenario Classifi. (CLDCLASS)

L2 --- Cloud Water Content (2B-CWC-RO)

Contain:

1. CERES derived cloud properties with MODIS data
2. CERES TOA radiative flux (SW, LW, and WN)
3. Vertical radiative flux profiles
4. Heating rate vertical profiles



C3M Data Used In This Study

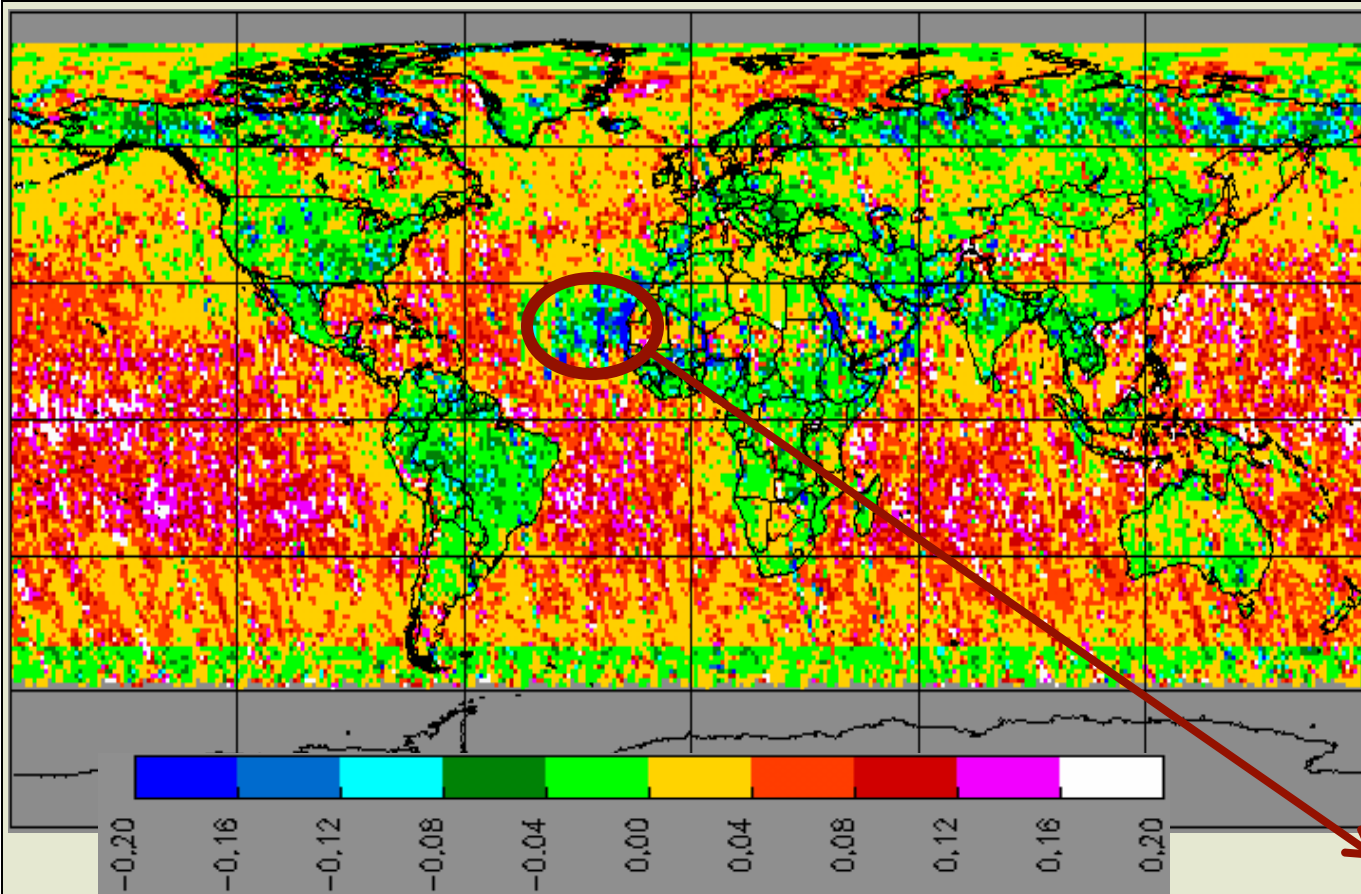
- With two CERES Clouds Editions:
C3M-Ed2 and C3M-Ed4
- 4 Seasonal Months of 2010:
January, April, July, October



Cloud Detection Comparisons
between CERES **Ed4** and CALIPSO
between CERES **Ed2** and CALIPSO

CALIPSO cloud detection with mid or high confidence





Cloud Fraction Difference between Ed4 and Ed2 (Ed4 – Ed2)

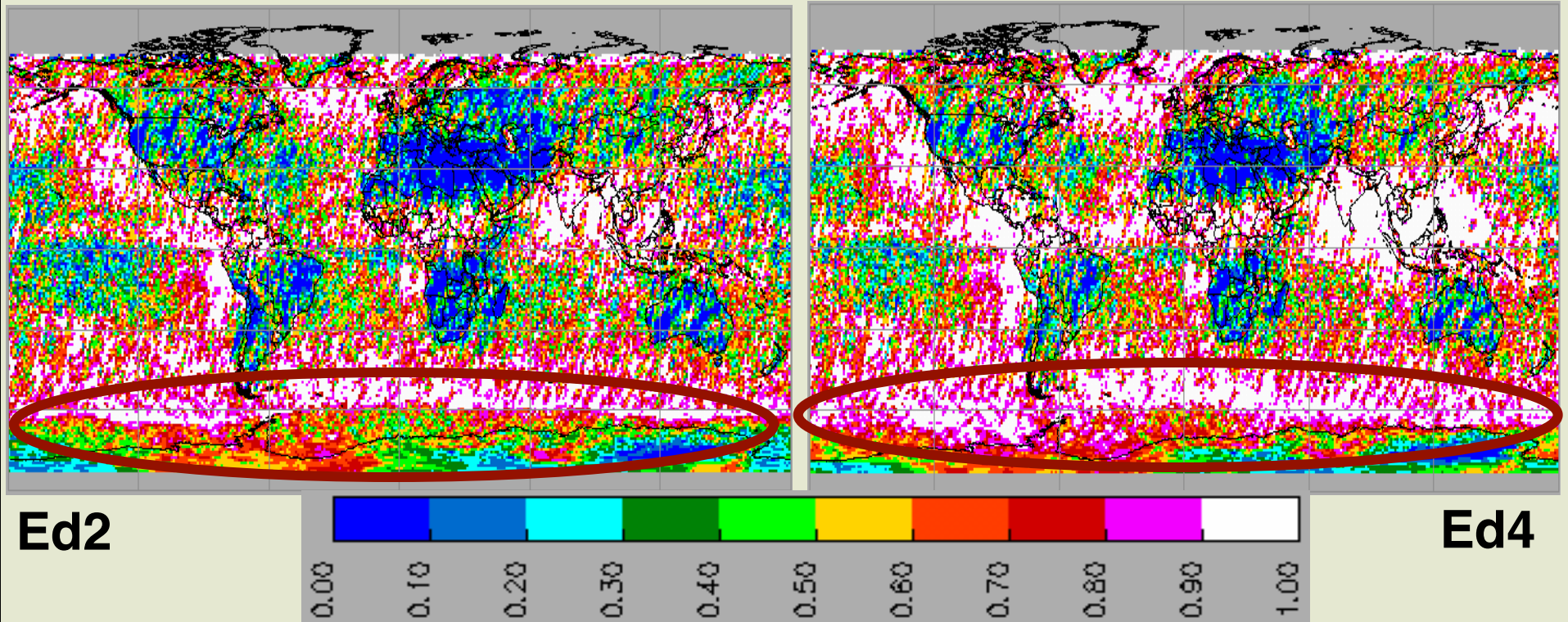
July 2010, Day Time,
MAC Data (Aqua-MODIS
nadir data 101 pixel
centered at CALIPSO
track)

Sahara Dust

		CALIPSO (60,801)			
		Ed2 (%)		Ed4 (%)	
		Clear	Cloud	Clear	Cloud
CERES	Clear	28.11	9.67	31.64	12.81
	Cloud	7.73	54.48	4.20	51.34
Agreement (%)		82.59		82.98	



Aqua-MODIS, C3M, July 2010, Cloud Fraction, Night Time



Zone 60 S – 90 S		CALIPSO (1,388,083)			
		Ed2 (%)		Ed4 (%)	
		Clear	Cloud	Clear	Cloud
CERES	Clear	11.78	19.67	10.33	11.62
	Cloud	3.11	65.43	4.56	73.48
Agreement (%)		77.21		84.81	

Artificial Line
eliminated in Ed4



CERES

CALIPSO

Ed2

Ed4

	Clear (%)	Cloud (%)	Clear (%)	Cloud (%)
Clear (%)	16.05	25.93	12.87	14.93
Cloud (%)	2.16	55.80	5.01	67.15
Agree (%)	71.85		80.02	

60-90N

(4.0 million)

Four Season Month 2010

Clear (%)	16.15	12.65	15.23	9.10
Cloud (%)	2.11	69.06	3.35	0.72.30
Agree (%)	85.22		87.53	

60-90N

(3.4 million)

Clear (%)	21.80	21.50	19.24	13.90
Cloud (%)	1.67	54.99	4.25	6.26
Agree (%)	76.79		81.82	

30S-30N

(10.2 million)

Night Time Ocean

Clear (%)	11.66	10.43	10.62	7.27
Cloud (%)	1.79	76.04	2.45	0.79.63
Agree (%)	87.71		90.24	

30-60S

(6.9 million)

Clear (%)	8.85	14.19	7.71	7.89
Cloud (%)	2.05	74.88	3.40	80.99
Agree (%)	83.73		88.69	

60-90S

(3.8 million)



CERES

CALIPSO

Ed2

Ed4

**Four
Season
Month
2010**

**Night
Time
Land**

	Clear (%)	Cloud (%)	Clear (%)	Cloud (%)
Clear (%)	20.20	29.46	21.26	22.95
Cloud (%)	3.98	46.29	4.26	51.49
Agree (%)	66.49		72.75	
Clear (%)	32.84	25.91	31.58	0.17.61
Cloud (%)	11.38	40.11	2.77	48.04
Agree (%)	72.94		79.61	
Clear (%)	32.16	24.16	30.49	17.15
Cloud (%)	0.92	42.75	2.24	50.11
Agree (%)	74.91		80.61	
Clear (%)	44.86	22.14	41.17	15.71
Cloud (%)	0.86	0.32.14	2.09	41.04
Agree (%)	77.00		82.20	
Clear (%)	28.95	25.99	29.67	25.26
Cloud (%)	81.30	36.31	5.30	38.83
Agree (%)	65.26		68.50	

60-90N

(3.4 million)

60-90N

(3.6 million)

30S-30N

(3.6 million)

30-60S

(0.4 million)

60-90S

(5.2 million)



CERES

CALIPSO

Ed2

Ed4

**Four
Season
Month
2010**

**Day
Time
Ocean**

	Clear (%)	Cloud (%)	Clear (%)	Cloud (%)
Clear (%)	15.99	11.83	15.70	10.98
Cloud (%)	3.22	68.93	3.66	69.67
Agree (%)	84.92		85.37	
Clear (%)	18.14	9.89	17.97	7.71
Cloud (%)	2.85	69.12	3.61	70.71
Agree (%)	87.26		88.67	
Clear (%)	27.48	18.65	25.60	13.76
Cloud (%)	3.13	50.73	4.95	55.69
Agree (%)	78.22		81.29	
Clear (%)	14.63	8.60	14.12	6.67
Cloud (%)	2.17	74.60	2.86	76.35
Agree (%)	89.23		90.47	
Clear (%)	7.93	4.78	8.01	4.01
Cloud (%)	1.00	86.27	1.08	86.89
Agree (%)	94.20		94.90	

60-90N

(3.2 million)

60-90N

(3.4 million)

30S-30N

(10.1 million)

30-60S

(6.4 million)

60-90S

(1.8 million)



CERES

CALIPSO

Ed2

Ed4

**Four
Season
Month
2010**

**Day
Time
Land**

	Clear (%)	Cloud (%)	Clear (%)	Cloud (%)
Clear (%)	22.19	15.86	22.92	16.67
Cloud (%)	3.33	58.57	3.23	57.10
Agree (%)	80.76		80.02	
Clear (%)	28.73	17.03	28.31	14.31
Cloud (%)	2.60	51.29	3.09	54.22
Agree (%)	80.02		82.52	
Clear (%)	30.30	18.15	32.43	18.96
Cloud (%)	2.65	47.97	2.05	46.34
Agree (%)	74.91		78.77	
Clear (%)	39.74	13.15	38.27	12.23
Cloud (%)	2.94	43.81	2.94	46.48
Agree (%)	83.55		84.75	
Clear (%)	45.35	12.89	43.09	11.68
Cloud (%)	4.48	37.25	6.85	38.31
Agree (%)	82.59		81.41	

60-90N

(2.5 million)

60-90N

(3.6 million)

30S-30N

(3.7 million)

30-60S

(0.4 million)

60-90S

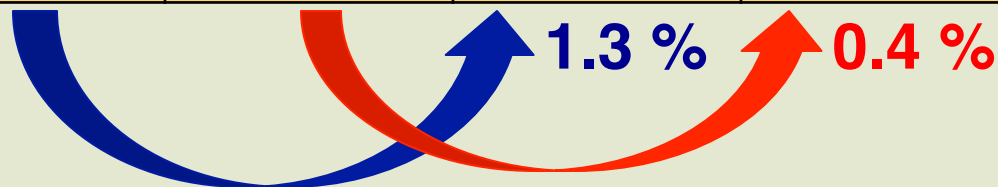
(2.5 million)



2010, All 4 seasonal months, **Day Time**

CALIPSO and CERES Cloud Detection Agreement

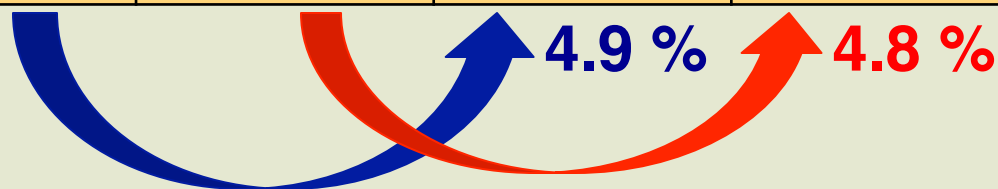
Global	Ed2 (%)		Ed4 (%)	
Month	Ocean	Land	Ocean	Land
January	85.80	82.66	87.14	82.72
April	82.65	77.36	83.88	77.92
July	83.82	79.78	86.23	80.32
October	87.22	80.86	87.57	81.36
4 months	84.87	80.17	86.21	80.58



2010, All 4 seasonal months, **Night Time**

CALIPSO and CERES Cloud Detection agreement

Global	Ed2 (%)		Ed4 (%)	
	Ocean	Land	Ocean	Land
January	78.17	68.56	83.66	75.03
April	80.82	67.62	85.15	72.61
July	81.00	71.44	85.37	73.78
October	81.50	73.01	86.78	78.33
4 months	80.37	70.16	85.24	74.94



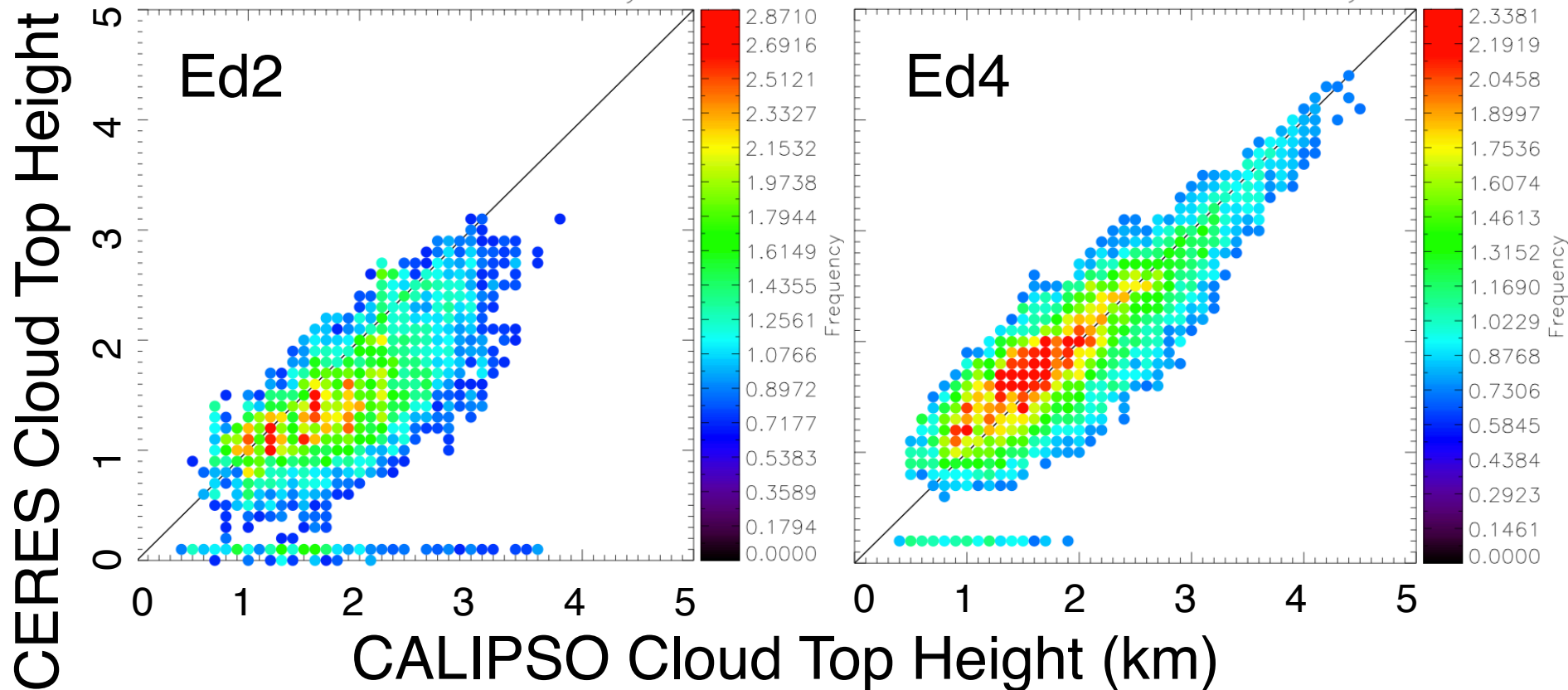
Cloud Top Height Comparisons For Water Clouds between CERES Ed4 and CALIPSO between CERES Ed2 and CALIPSO

Conditions:

- Single Layer
- CERES-MODIS cloud phase = water clouds
- CALIPSO cloud top height – surface elevation < 5 km
- Binning size = 0.1 km (0 – 5 km)



2010, 4 Seasonal Months, **Day Time**, **Water Cloud**, **Land**



diff = - 0.66 (km)
 diff std = 1.15 (km)
 rmsd = 1.32 (km)

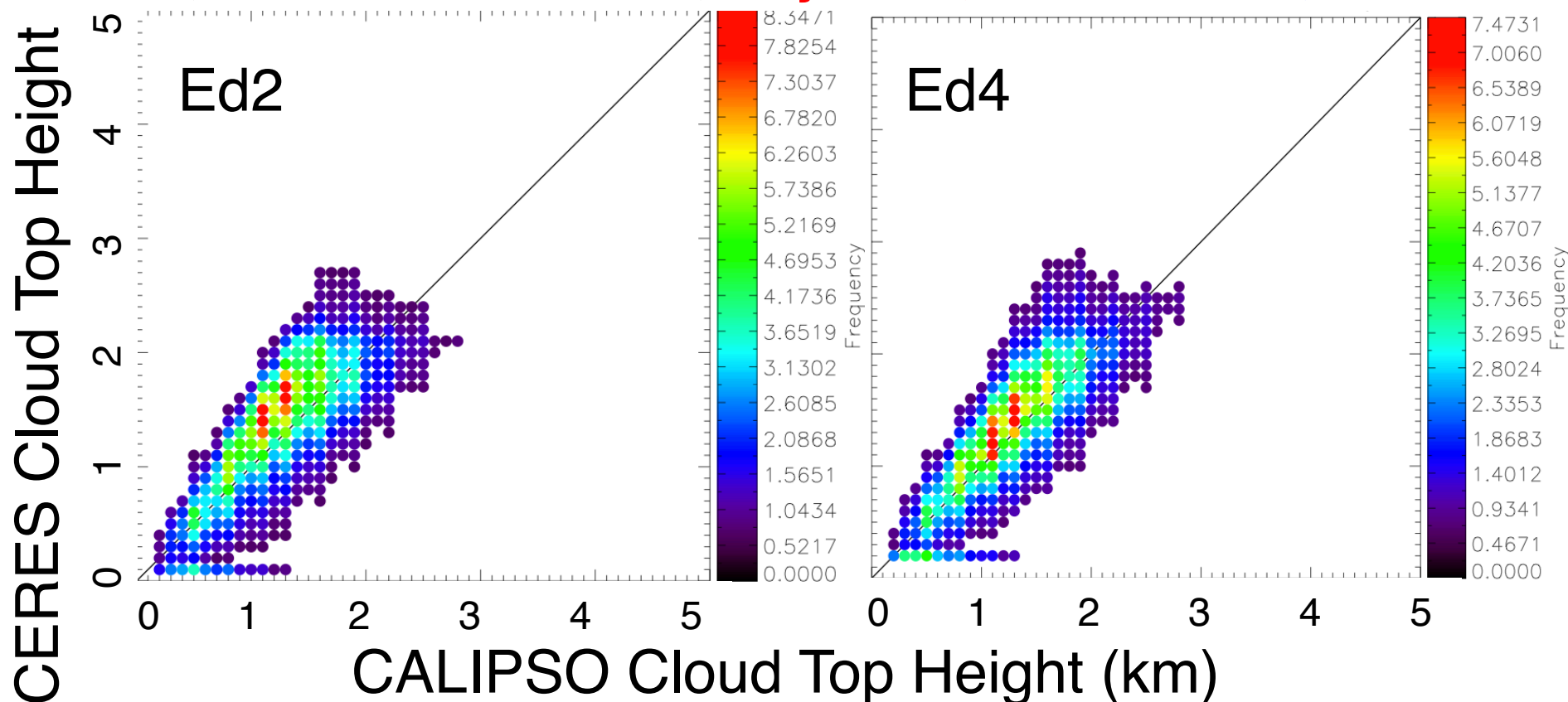
diff = CERES – CALIPSO (km)

Snow-Free Land

diff = - 0.22 (km)
 diff std = 1.10 (km)
 rmsd = 1.12 (km)



2010, 4 seasonal months, **Day Time, Water Cloud, Ocean**

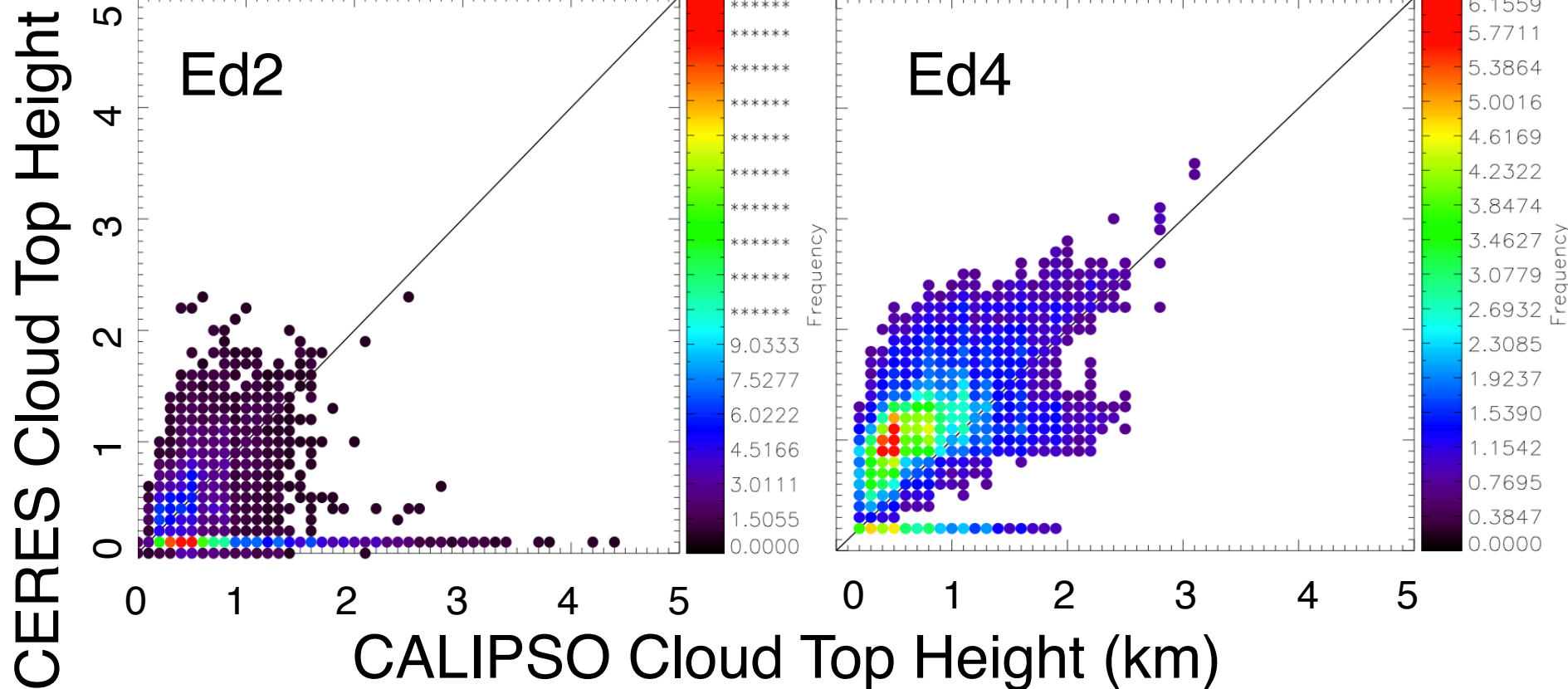


diff	= 0.024 (km)	diff = CERES – CALIPSO (km)	diff	= - 0.015 (km)
diff std	= 0.753 (km)		diff std	= 0.733 (km)
rmsd	= 0.754 (km)		rmsd	= 0.733 (km)

Snow-Free Ocean



2010, 4 seasonal months, Day Time, Water Cloud, Snow



diff = - 0.46 (km)
 diff std = 1.18 (km)
 rmsd = 1.26 (km)

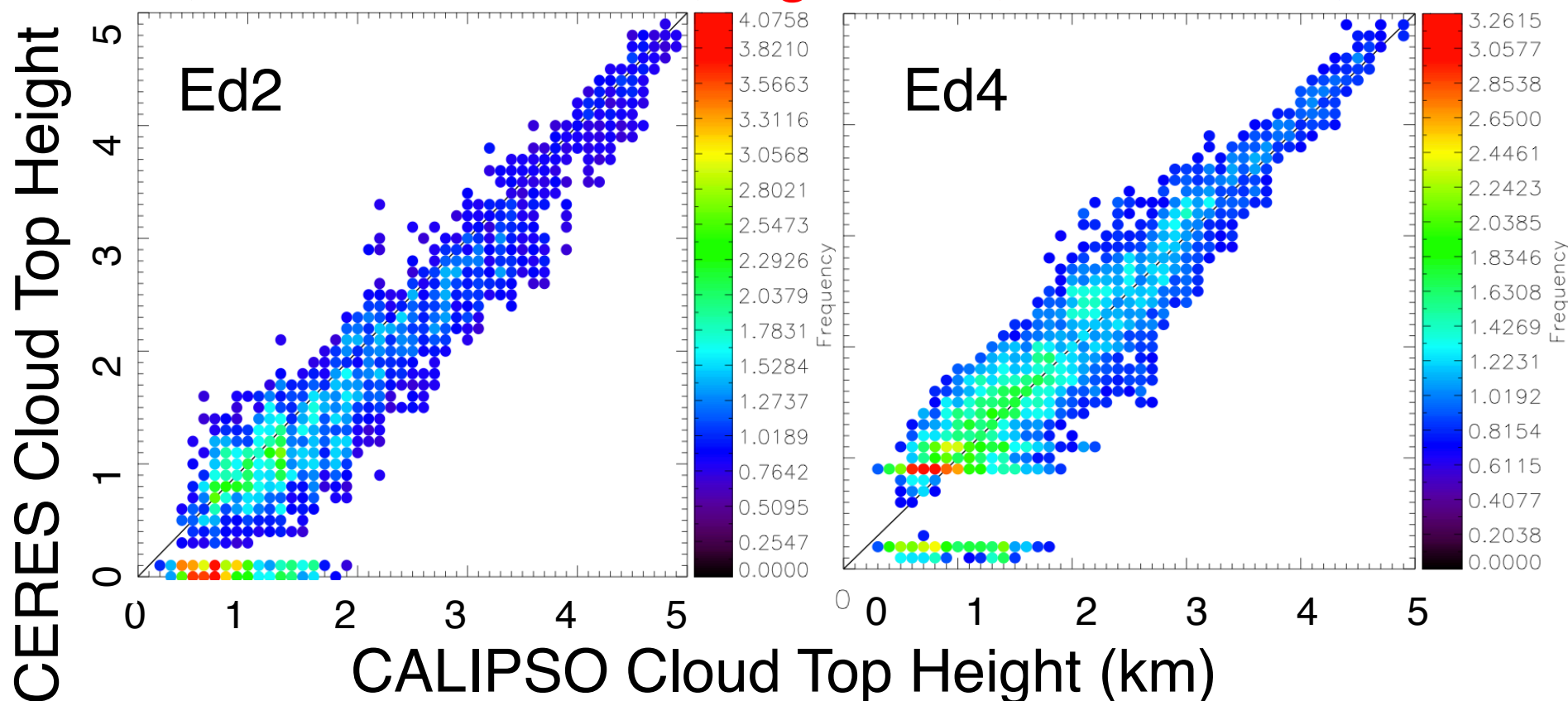
diff = CERES – CALIPSO (km)

Snow Covered

diff = 0.07 (km)
 diff std = 1.04 (km)
 rmsd = 1.04 (km)



2010, 4 seasonal months, Night Time, Water Cloud, Land



diff = - 0.38 (km)
 diff std = 0.92 (km)
 rmsd = 0.99 (km)

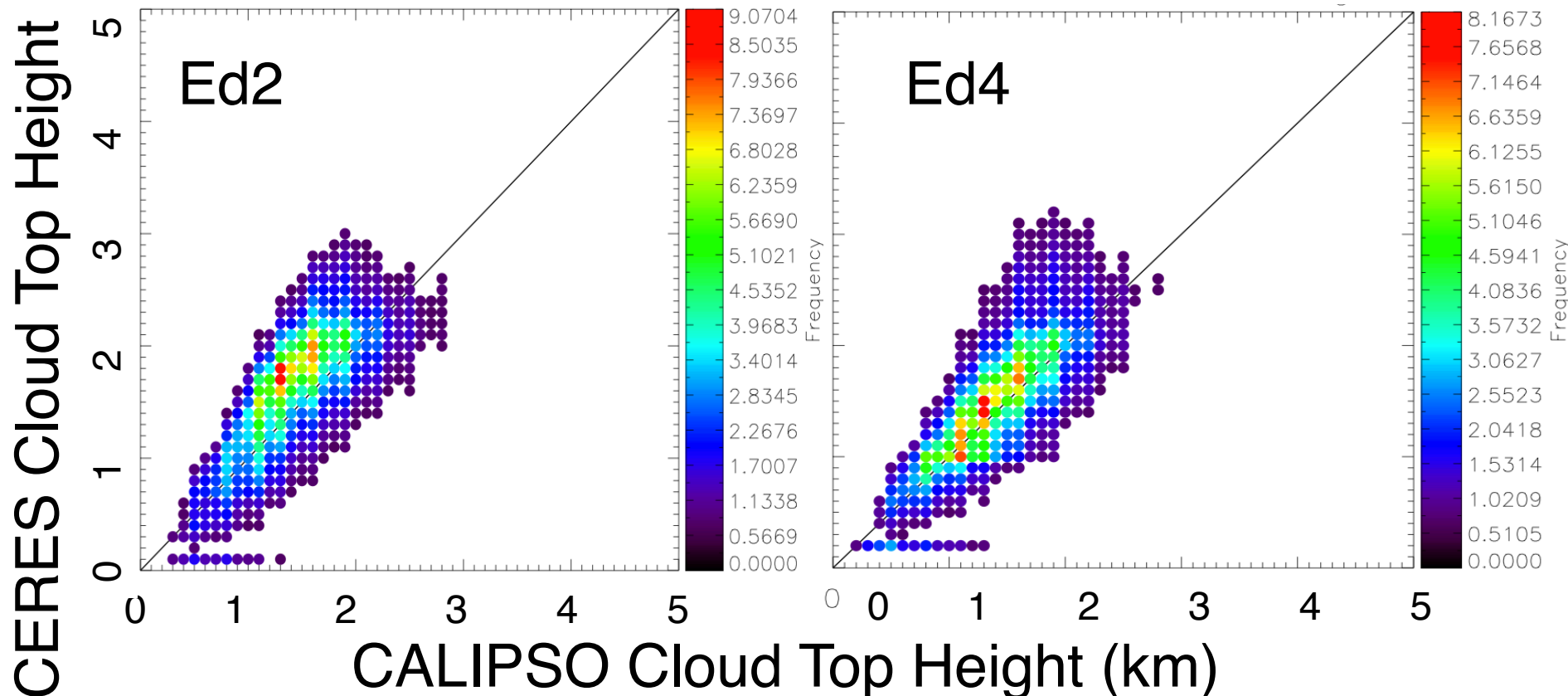
diff = CERES – CALIPSO (km)

Snow-Free Land

diff = - 0.01 (km)
 diff std = 1.00 (km)
 rmsd = 1.01 (km)



2010, All 4 seasonal months, **Night Time, Water Cloud, Ocean**



diff = 0.08 (km)
 diff std = 0.76 (km)
 rmsd = 0.76 (km)

diff = CERES – CALIPSO (km)

Snow-Free Ocean

diff = 0.02 (km)
 diff std = 0.69 (km)
 rmsd = 0.69 (km)



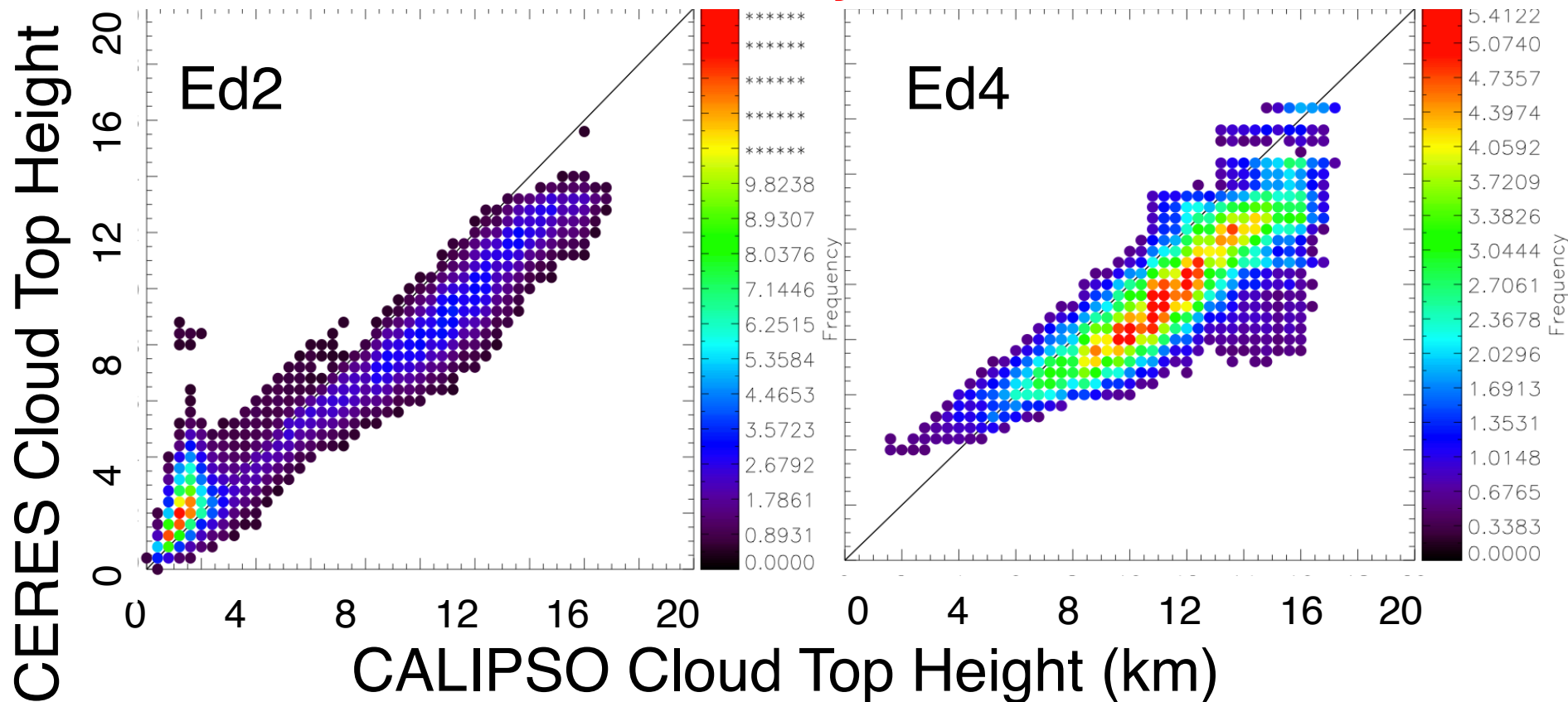
Cloud Top Height Comparisons for Ice Cloud between CERES Ed4 and CALIPSO between CERES Ed2 and CALIPSO

Conditions:

- Single Layer from CALIPSO
- CERES-MODIS cloud phase = ice clouds
- Binning size = 0.4 km (0 – 20 km)



2010, 4 seasonal months, Day Time, Ice Cloud, Ocean

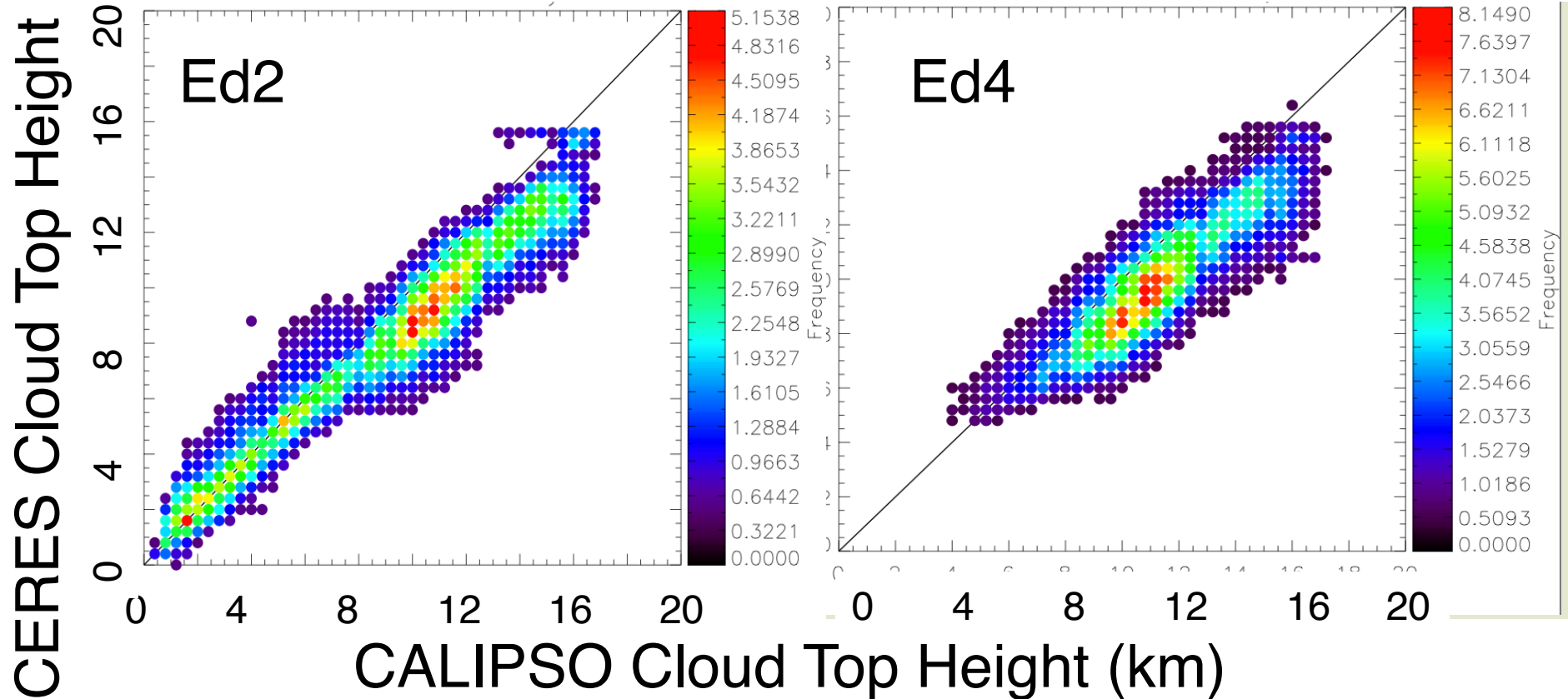


diff	= -0.94 (km)	diff = CERES – CALIPSO (km)	diff	= -1.10 (km)
diff std	= 2.59 (km)		Diff std	= 2.29 (km)
rmsd	= 2.76 (km)		rmsd	= 2.54 (km)

Snow-Free Ocean



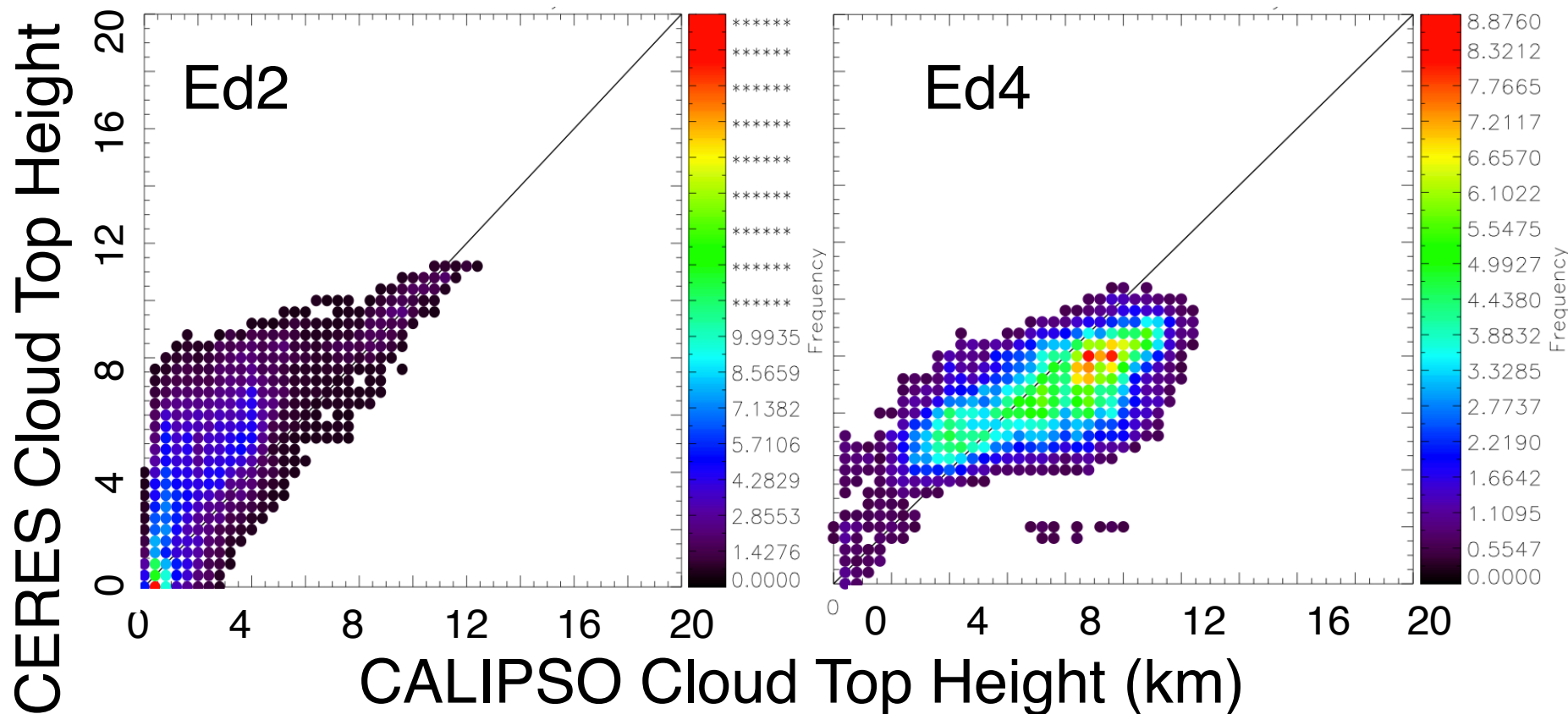
2010, 4 seasonal months, **Day Time, Ice Cloud, Land**



diff = -0.78 (km)	diff = CERES – CALIPSO (km)	Diff = - 1.40 (km)
diff std = 2.53 (km)		Diff std = 2.51 (km)
rmsd = 2.65 (km)	Snow-Free Land	rmsd = 2.88 (km)



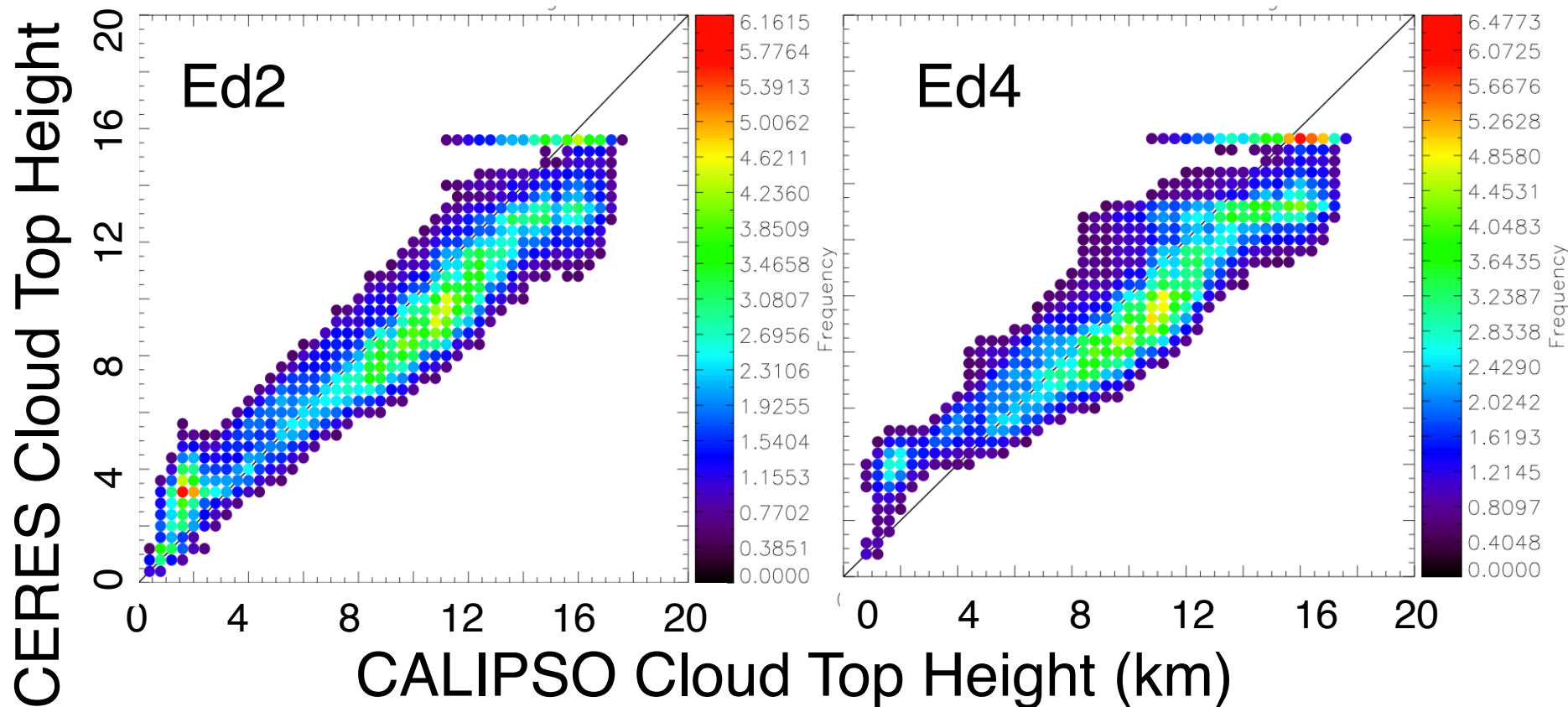
2010, 4 Seasonal Months, Day Time, Ice Cloud, Snow



diff = 1.32 (km)	diff = CERES – CALIPSO (km)	diff = - 0.77 (km)
diff std = 2.51 (km)		Diff std = 2.45 (km)
rmsd = 2.84 (km)	Snow Covered	rmsd = 2.57 (km)



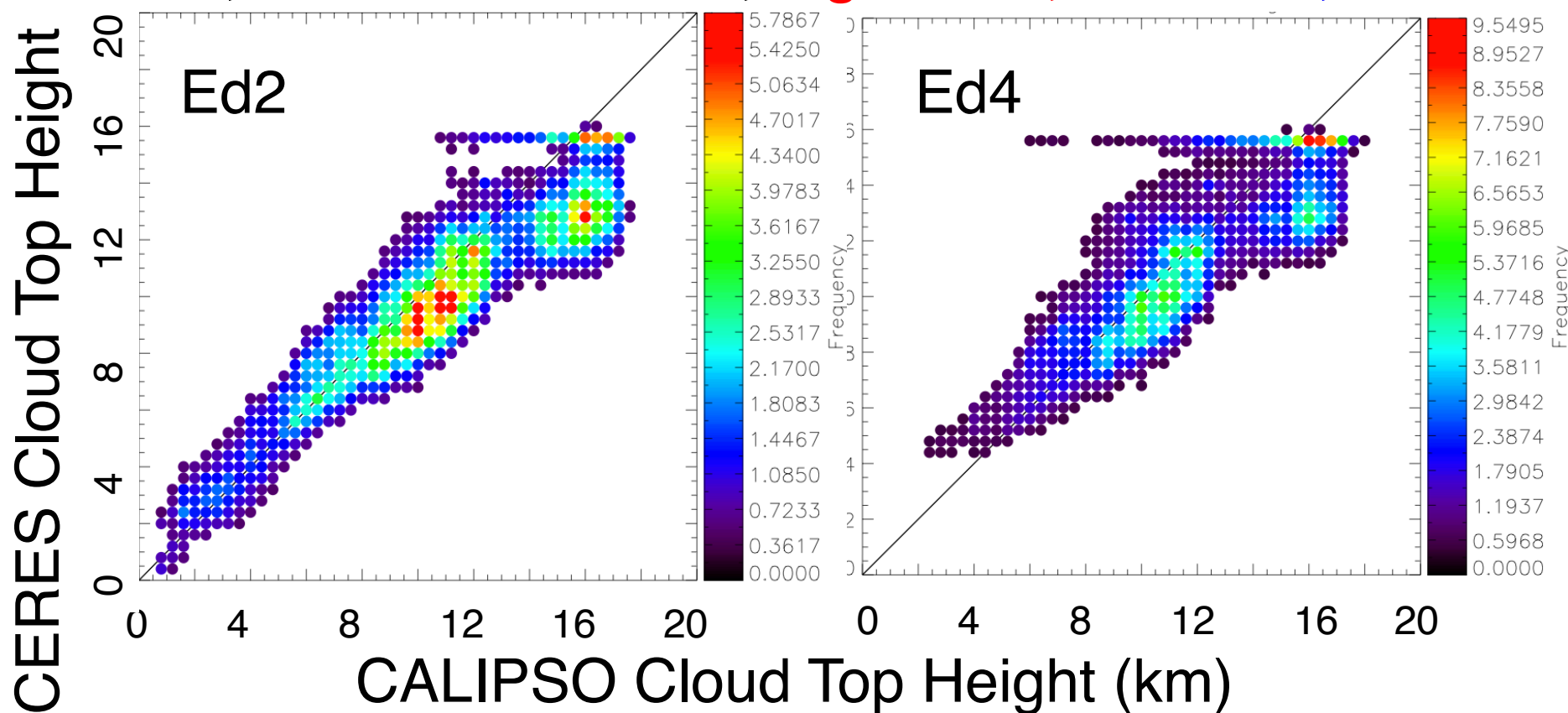
2010, 4 Seasonal Months, Night Time, Ice Cloud, Ocean



diff	= - 0.49 (km)	diff = CERES – CALIPSO (km)	diff	= - 0.24 (km)
diff std	= 2.24 (km)		Diff std	= 2.27 (km)
rmsd	= 2.29 (km)	Snow-Free Ocean	rmsd	= 2.28 (km)



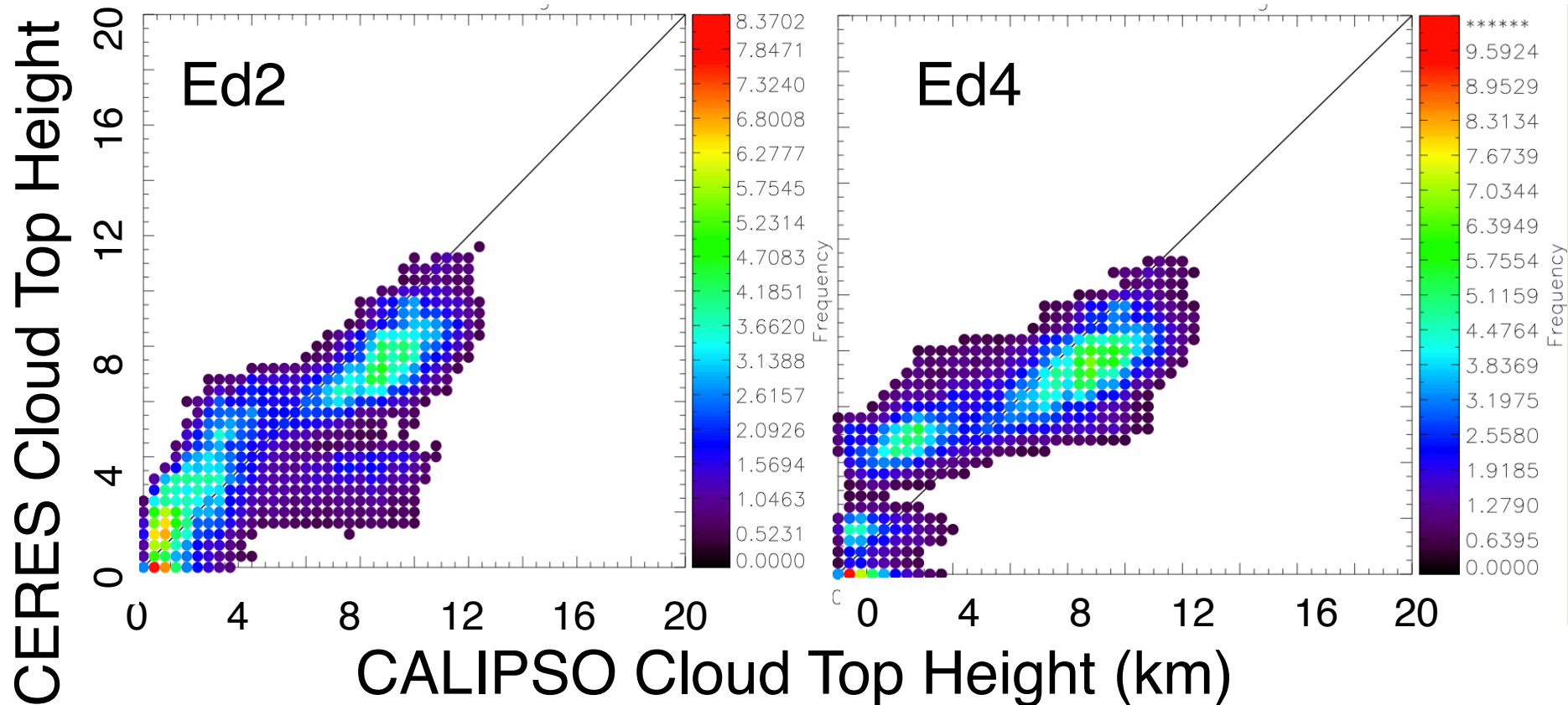
2010, 4 Seasonal Months, Night Time, Ice Cloud, Land



diff	= -0.63 (km)	diff = CERES – CALIPSO (km)	Diff	= -0.13 (km)
diff std	= 2.26 (km)		diff std	= 2.54 (km)
rmsd	= 2.35 (km)	Snow-Free Land	rmsd	= 2.54 (km)



2010, All 4 seasonal months, **Night Time, Ice Cloud, Snow**



diff	= - 0.96 (km)	diff = CERES – CALIPSO (km)	diff	= - 0.24 (km)
diff std	= 2.73 (km)		diff std	= 2.69 (km)
rmsd	= 2.90 (km)	Snow Covered	rmsd	= 2.70 (km)

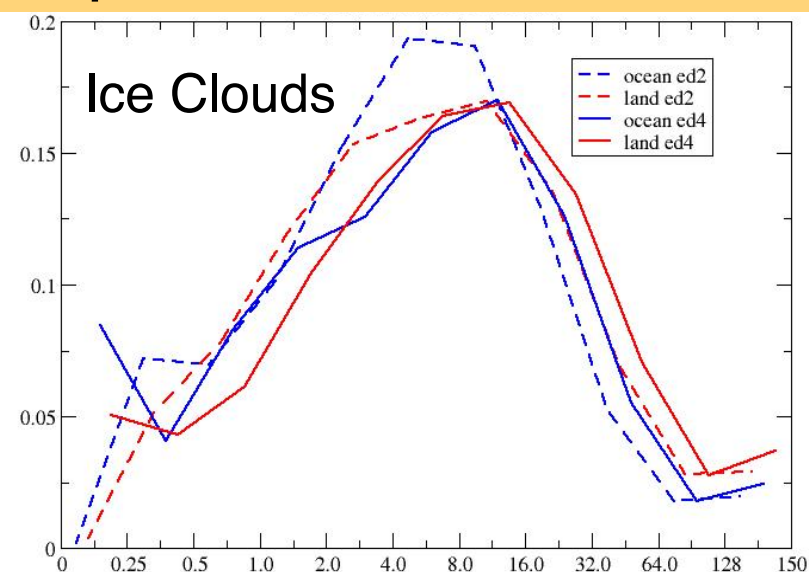
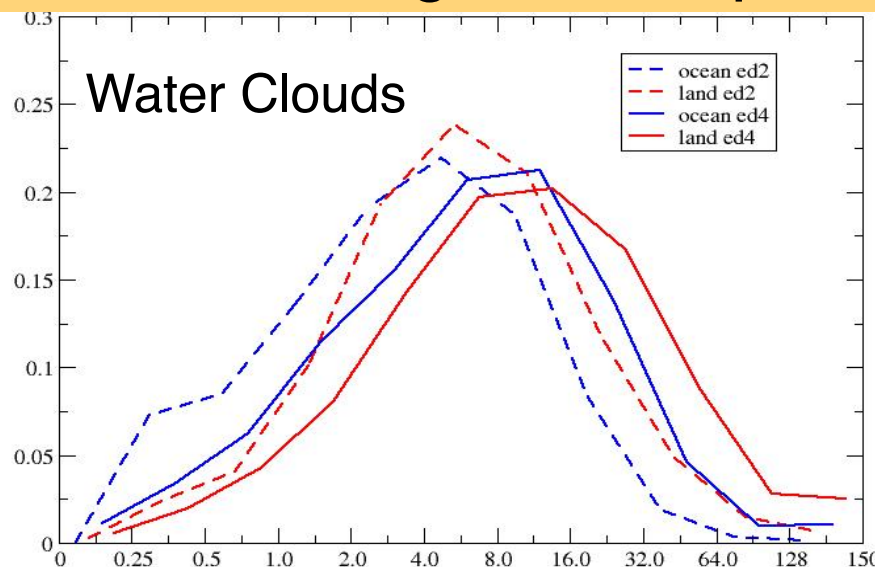


Cloud Optical Depth Comparisons between CERES Ed2 and Ed4



2010, 4 Seasonal Months, Aqua-MODIS

Histogram of Optical Depth, **Snow Free**



Water Clouds:

Ocean

Ed2: Mean = 2.2, Stdev = 9.8

Ed4: Mean = 3.3, Stdev = 16.5

Land

Ed2: Mean = 7.3, Stdev = 17.2

Ed4: Mean = 8.9, Stdev = 26.4

Ice Clouds:

Ocean

Ed2: Mean = 3.0, Stdev = 19.4

Ed4: Mean = 6.8, Stdev = 24.9

Land

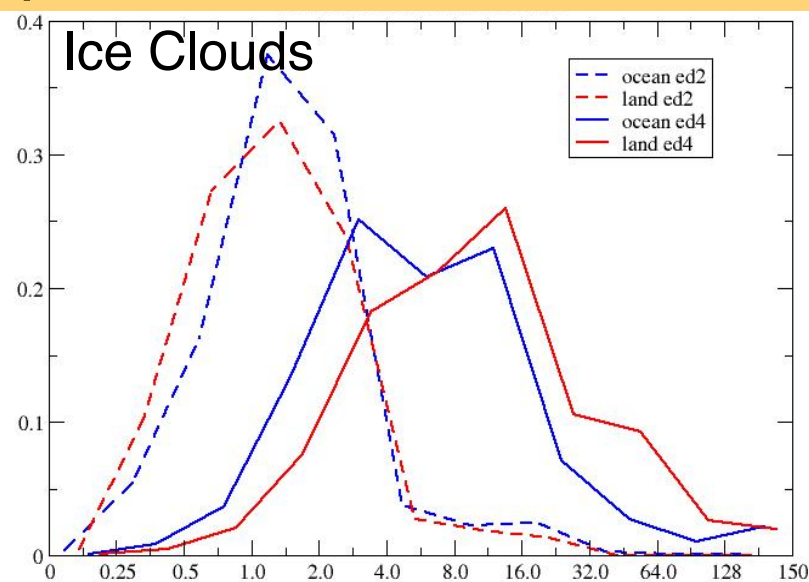
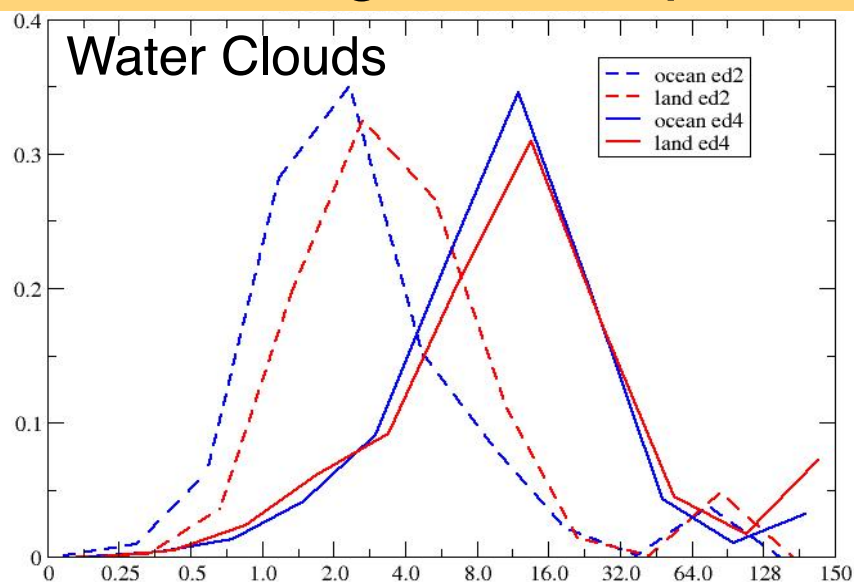
Ed2: Mean = 9.1, Stdev = 26.1

Ed4: Mean = 11.0, Stdev = 31.0



2010, 4 Seasonal Months, Aqua-MODIS

Histogram of Optical Depth, **Snow Covered**



Water Clouds:

Ocean :

Ed2: Mean = 5.0, Stdev = 12.47

Ed4: Mean = 8.4, Stdev = 28.11

Land:

Ed2: Mean = 6.5, Stdev = 13.3

Ed4: Mean = 14.5, Stdev = 37.9

Ice Clouds:

Ocean

Ed2: Mean = 1.4, Stdev = 6.2

Ed4: Mean = 8.7, Stdev = 23.5

Land

Ed2: Mean = 0.9, Stdev = 3.9

Ed4: Mean = 10.1, Stdev = 24.7



Summary

- Ed4 CF regional improvement: Sahara dust, artificial lines...
- Clouds detection improvement:
 - Day time improved by $\sim 1\%$ (ocean and land)
 - Night time improved by $\sim 5\%$ (ocean and land)
- Water cloud top height improvement:
 - Day time:
 - Land: 0.66 (Ed2) --- -0.22 (Ed4) km
 - Ocean: 0.024 (Ed2) --- -0.015 (Ed4) km
 - Snow: -0.46 (Ed2) --- 0.07 (Ed4) km
 - Night time:
 - Land: -0.38 (Ed2) --- -0.01 (Ed4) km
 - Ocean: 0.08 (Ed2) --- 0.02 (Ed4) km
- Ice cloud top height:
 - cloud phase changes removed some of ice clouds to water clouds
 - ~ 1 km lower than CALIPSO



Corrections to Aqua & VIIRS Validations in Cloud Algorithm Update

- MODIS data were matched with 5-km CALIPSO data
 - no 80 km cloud detections considered
 - CALIPSO/MODIS *cloud/clear*, if MODIS $CF < 0.01$
cloud/cloud, if MODIS $CF > 0.01$
clear/clear, if MODIS $CF < 0.99$
clear/cloud, If MODIS $CF > 0.99$
- This approach maximized matches between CALIPSO & MODIS
 - if 5 km CALIPSO data are used, then CF cutoffs should be 0.5, not 0.01 or 0.99
 - using 0.5 as threshold reduces range of matches from 0.8 to 0.95 down to 0.77 to 0.92, more reduction if 80-km CALIPSO clouds are used
- New results have been generated & included in Cloud Update slides

